

**Marufur Rahim  
Surendra Kadakla**

10                   **Cathode Coating Dispersion**

**FIELD OF THE INVENTION**

This invention relates to one pot high temperature curable thermoset cathode coating dispersions. The formulations contain graphite and/or carbon black, acrylic resin or butadiene acrylonitrile or styrene butadiene or epoxy and/or 15 epoxy ester. The coatings are cured with appropriate crosslinkers such as melamine and/or phenolic resin and/or carbodiimide and acid catalyst. These coatings are suitable for use in batteries, fuel cells, capacitors and other energy storage devices.

20                   **BACKGROUND OF THE INVENTION**

Alkali battery dry cells are manufactured by pre-forming a steel can with a nickel plating inside the can. The cathode, a compressed mixture of manganese dioxide, carbon and possibly other additives is positioned inside the can in the form of a hollow cylinder which is in close contact with the can inner surface.

25                   Alternatively, rings of cathode materials can be formed outside the cell and then pushed into the can. The inside of the can is treated with a conductive dispersion which is placed between the inside surface of the can and the cathode mixture in order to improve the electrical contact between the can and the cathode mixture and to prevent corrosion of the nickel layer and the can from the electrolytes.

5           In the past various emulsions have been utilized in an attempt to  
maximize electrical contact and prevent corrosion in batteries. These emulsions  
generally contain graphite and/or carbon black in combination with a binder. For  
example, U.S. Patent No. 4,810,600 utilizes a dispersion containing graphite  
and/or carbon black in combination with a binder of a) vinyl acetate and ethylene,  
10          b) vinyl acetate and vinyl chloride, c) styrene and butadiene, or d) vinyl acetate,  
vinyl chloride and ethylene. In addition, other dispersions have been utilized  
containing binders of aromatic polyurethane, styrene acrylic, aliphatic polyester  
polyurethane, vinyl acetate acrylic, aliphatic polycarbonate urethane and  
fluoropolymer. All the above dispersions were used as a thermoplast which  
15          requires no crosslinker during the cure. After final cure on nickel plated steel all of  
these various dispersions exhibited some form of failure when subjected to high  
concentrations of potassium hydroxide. The dispersions in some cases showed  
high electrical resistance after the KOH test as opposed to before the test and in  
some cases the binders either became soft or lost adhesion when sprayed on the  
20          nickel plated panel, dried at 80°C for 20 minutes and then immersed in 40% KOH  
solution for 72 hours at 80 °C. One of the main reasons for the softness is due to  
lower Tg (glass transition temperature) of the binder. Harder coatings which  
require higher Tg and will not soften at higher temperature, can be achieved by a  
crosslinking reaction with other resins.

25          The objective of the present invention is to provide one component, heat  
activated crosslinking conductive coatings for use in batteries, fuel cell, capacitor  
or other energy storage devices. The dispersion is made of graphite and or

5 carbon black, binders, crosslinkers and a catalyst. The coatings form a stable  
electrically conducting cathode layer which in turn improves the storage and  
discharge properties of the energy device. The improved properties of the  
coating also include the strong adherence of the coating with the cathode surface  
when it is subjected to potassium hydroxide and/or elevated temperatures. It is a  
10 further objective to provide a dispersion which may be utilized on the bipolar  
plates of a fuel cell or as a current collector for electrodes used in an  
ultracapacitor.

#### SUMMARY OF THE INVENTION

15 The dispersion is a one pot system comprised of styrene acrylic and  
epoxy ester in which melamine and/or carbodiimide are added as cross linkers.  
The formulation may also contain a blocked acid to catalyze the cross linking  
reaction. A similar dispersion is also formulated by using butadiene acrylonitrile or  
styrene butadiene and epoxy ester which also include the above cross linkers  
20 and catalysts. Further, a dispersion may also consist of epoxy and/or epoxy ester  
and acid catalysts, phenolic resin and/or melamine as crosslinkers. These one  
pot systems have shown excellent resistance to alkali at higher temperature and  
generate good conductivity when applied on a nickel plated steel. The formulation  
containing butadiene acrylonitrile has also shown good acid resistance as well.  
25 Consequently, these coatings can be used as a cathode coating for energy  
storage devices such as alkaline batteries that will generate suitable

5 conductivities as well as an excellent resistance to chemicals in the alkaline batteries, fuel cells and capacitors and other energy storage devices.

#### DETAILED DESCRIPTION OF THE INVENTION

The dispersion of the present invention is comprised of a graphite and/ or carbon black with at least two kinds of resins which contain carboxylic functionality for cross linking reactions. Similarly, a dispersion of the second kind is formulated by using epoxy and phenolic resin and or melamine. The hydroxyl group of epoxy crosslinks with melamine and the epoxy group crosslinks with phenolic resin. The cross linking reactions also occur only after applying higher temperature for a period of time. The cross linking reactions generate a coating which is very resistant to alkaline and acid environment and produces a good electrically conducting layer.

The graphite dispersion is specifically developed as a cathode current collector for alkaline batteries. This dispersion serves as a coating on a current collector and prevents the corrosion of the electrode from the corrosive chemical environment inside the alkaline batteries. The dispersion, specifically the formulation containing butadiene-acrylonitrile or epoxy as a binder, is not only alkaline resistant but also resistant to acidic environments. Consequently, the coating can be used as well in a fuel cell where higher resistance of the current collector coating is desired to the bipolar electrodes.

5           These dispersions are primarily utilized for coating a cathode holder or  
battery can. Along the same line these dispersions are also suitable for  
application as current collector coatings on electrodes of an ultracapacitor. These  
coatings form the connecting layer that improves the electrical contact between  
the electrode and the electrolyte, which may be aqueous or non-aqueous in  
10          nature. Preferred graphites for use in the dispersion are natural or synthetic  
graphites of high purity and high crystallinity. In the dispersion mixture, the  
electrically conductive graphite is used in the amount of about 30 – 90% by  
weight of the total solid. To prepare a proper dispersion, demineralized water is  
used as a dispersing media. Also, to obtain problem free coatings the following  
15          additives are added. For example, defoamers, preservatives, surface agent  
and/or dispersing agents may be utilized. Defoamers which may be utilized  
include BYK 022, BYK 019, BYK 24 (BYK-Chemie), DF 37, DF-40, DF 120, DF  
70, DF-75, DF-58, DF 60, DF-62, DF 66, DF 574, DF 696 (Air Products &  
Chemicals, Inc.), Nalco 2300, Nalco 2305, Nalco 2302 (Rohm & Haas Co.), Triton  
20          CF-32 (BASF Corp.), L-62 (Witco), Coatsil 1300 (Condea Vista) and Alfol 8  
alcohol. Preservatives which may be utilized include Busan 85, Busan 2024,  
Busan 1024 (Buckman Laboratories), Hyamine 10-X, Hyamine 2389 (Rohm &  
Haas Co.), Promexal X50 (Zeneca), Parmetol DF 18 (S&M Special Additives),  
Kathon 886 (Rohm & Haas Co.) and Nuosept 101 (Creanova). Dispersing agents  
25          which may be utilized include, Busperse 229 (Buckman Laboratories), Tamol N,  
Tanol 731, Tamol 850, Tamol SN Rohm & Haas Co.), Daxad 30-30, Daxad 11,  
Daxad 15, Daxad 19 (W&R Grace Co.), CT-136, CT 141, CT 151, CT 161, CT

5        171 (Air Products & Chemicals, Inc.), Disperbyk 182, Disperbyk 190 and  
Disperbyk 185 (BYK-Chemie). Wetting agents which may be employed include  
Tween 20 (Spectrum Quality Products), Orotan and Silwet L-7068 (Witco).  
Surfactants which may be utilized include 104A, 104B, 104DPM, 104E, 104H,  
104NP and 104PA (Air Products & Chemicals, Inc.), and BYK 333.

10              In a preferred embodiment, the additives comprise from about 0.01 to  
about 5% of the total formulation weight. In an especially preferred embodiment,  
a wetting agent may also be added to the mixture.

In order to form a suitable resin dispersion the graphite and or carbon  
black are mixed with acrylic latex and epoxy ester. The acrylic latex in this  
15 application contains styrene and acrylic or butadiene resin in the polymeric  
backbone of the binder system. The epoxy ester preferably has an acid number  
of 10 – 100. The ratio of acrylic to styrene or butadiene resin is preferably in the  
range of about 0.01 to about 9. Similarly, a second dispersion is developed for  
the same application which contains graphite and or carbon black in combination  
20 with butadiene acrylonitrile and epoxy ester. All of the above binders contain  
carboxylic functionality to provide the crosslinking reaction with melamine and or  
carbodiimide. A third dispersion is made with graphite and/or carbon black which  
contains epoxy and epoxy ester. In addition, the dispersion also contains  
melamine and phenolic resin as crosslinkers. In order to achieve proper  
25 conductivity for the desired application, it is necessary to prepare the mixture with  
the proper ratio of graphite and/or carbon black to binders. For example, for use  
with battery cans the proper ratio of graphite and/or carbon black to binder is in

5 the range of about 1 to 6, with a preferred range of about 1 to 4. The overall water content of the dispersion is preferably in the range of about 30 – 90% by weight and the graphite and/or carbon black mixture is preferably about 10 – 60% by dry mass weight.

A stable dispersion is formed in the presence of the proper additives and  
10 the binders. The viscosity ranges from 50 - 1200 mPa-sec. For proper curing the dispersion also contains one or more crosslinkers and an acid catalyst. The preferred crosslinkers are melamine, carbodiimide, phenolic or mixtures thereof. The acid catalyst is used to catalyze the reaction between the melamine and the binders. A curing agent may be utilized comprising a melamine and preferably a  
15 partially alkylated melamine with a higher imino group

Preferred crosslinkers include fully or partially alkylated melamine. Available crosslinkers include C-327, C-324, C-325, C-1158, C-323, C-303, C-350, C-370, C-385, C-1123 (CYTEC) and Ucarlink XL 29SE (Union Carbide) .

The reaction between the carboxylic functionality and melamine is  
20 catalyzed by sulfonic acid of various types including blocked sulfonic acids. More specifically the amine salt of para-Toluene Sulfonic Acid (p-TSA), such as BYK-Catalyst 450, BYK-Catalyst 460 ( BYK Chemie), Nacure 2107 and Nacure 2500, Nacure 49-110, (King Industries, Inc.), or epoxy blocked Dinonylnaphthalene Sulfonic acid, such as Nacure 1419 (King Industries Inc.), CyCat 296-9 catalyst  
25 (Cytec) or Nacure 49-110.

Preferred phenolic resins include Phenodur PR 308, Phenodur PR 307, Phenodur VPW 1942/52WA (Solutia).

5         Following its preparation, the coating is then applied to the surface via  
pouring, brushing, spraying or dipping and cured at elevated temperature. The  
water may be removed by allowing it to dry, by warming or by application of a  
vacuum. A preferred curing temperature is within the range of about 100 °C – to  
about 250 °C. Depending upon the chosen curing process, the time of curing  
10         ranges from 15 seconds to 16 minutes. The rate of curing can be controlled by  
changing the amount of crosslinkers and the catalysts. After curing, a  
mechanically and chemically resistant, electrolyte insoluble protective film  
remains on the surface. The resistivity of the resulting coating is about 5 – 100  
ohm per square. The resistance of the protective coating formed by the  
15         dispersion is not more than twice the initial value after the coating has been  
exposed to a 40% KOH solution for a period of 72 hours at 80 °C. The amount of  
coating to be applied is selected so that the film thickness of the resulting  
protective film after evaporation of the water is preferably about 5 – 200 microns  
and most preferably about 20 – 100 microns. A uniform thickness is obtained via  
20         the pseudoplastic and thixotropic properties of the dispersion.

The invention may be better understood by reference to the following  
examples which are intended for the purpose of illustration and are not to be  
construed as in any way limiting the scope of the present invention.

#### EXAMPLES

25         Two formulations were prepared by the following steps.  
1. Load 90% demineralized water, dispersant and cellulose into ring mill. Agitate  
5-10 minutes or until dissolved.

5      2. Add defoamer, carbon black and graphite powder  
3. Circulate mill for 5 hours or until minimum Hegman of 5.0 is achieved.  
4. Make letdown as follows: Premix epoxy ester and DMEA before adding to the  
batch then let it mix for 10 minutes. Then add the latex and melamine and or  
carbodiimide and let it mix for 15-20 minutes. Before adding the catalyst, the  
10     batch temperature is adjusted to about 32 °- 35 °C and then the catalyst is  
added. The viscosity is adjusted with water and PH with DMEA and or  
ammonia.

The components of each formulation are set out in Example 1 and 2.

15     EXAMPLE 1

	Carbon black (Vulcan XC-72 pellets)	3.030 grams
	Cellulose	0.69
	Dimethylethanolamine	0.31
20	Defoamer	0.16
	Dispersion Agent	0.77
	Demineralized Water	49.92
	Synthetic Graphite (graphite 39 powder)	20.63
25	Chempol 010-0453	2.470
	Neocryl A-662	17.28
	Cymel 323	4.63
	Nacure X49-110	0.25
		100 grams

## EXAMPLE 2

	Carbon black (Vulcan XC-72 pellets)	3.030 grams
	Cellulose	0.69
10	Dimethylethanolamine	0.25
	Defoamer	0.16
	Dispersion Agent	0.77
	Demineralized Water	45.64
	Synthetic Graphite (graphite 39 powder)	20.63
15	Chempol 010-0453	2.470
	Tylac 97767	22.74
	Cymel 323	3.86
	Nacure X49-110	0.25
20	XL 29SE	1.23
		100 grams

## EXAMPLE 3

	Carbon black (Vulcan XC-72 pellets)	3.030 grams
	Cellulose	0.69
10	Dimethylethanolamine	0.48
	Defoamer	0.16
	Dispersion Agent	0.77
	Demineralized Water	53.07
	Synthetic Graphite (graphite 39 powder)	20.63
15	Chempol 010-0453	2.470
	Phenodur VPW 1942/52WA	13.82
	Cymel 323	4.63
	Nacure X49-110	0.25
20		100 g

The resulting coatings from Examples 1 and 2 were sprayed on nickel-plated panels and cured at 150 °C for 3 minutes or 1 minute at 205 °C. The coating from Example 3 were baked at 205° C for 3 minutes. The nickel-plated panel was then placed in a 40% KOH solution for 72 hours at 80°C. The panels were then removed from the solution, washed with running water and then dried in an oven for 30 minutes at 60°C. A tape test was performed wherein Scotch brand tape was firmly pressed onto each sample and then slowly removed at a 90 degree angle. Excellent adhesion was shown by each sample in that none of the coating was removed via the tape test.

5           While the invention has been described with particular reference to certain embodiments thereof, it will be understood that changes and modifications may be made by those of ordinary skill within the scope and spirit of the following claims.